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WATER SUPPLY BY NATURAL FILTRATION.

BY LATHAM ANDERSON.

Water supply systems using naturally filtered water comprise two classes:

1st.—Those using ground or soil water, and.

2d.—Those drawing water from bars in or on the banks of running streams.

In the first, water may be collected either in large wells or galleries walled with stone, or by means of gangs of driven wells. Probably the most noted example in this country of a large curbed well is that in Prospect Park, Brooklyn.

The driven wells yielding ground water are so generally used as not to require further mention and they will not be further discussed in this paper, whose special object it is to call attention to the second class, i. e., those using naturally filtered stream water.

According to Humber and Kirkwood the following are the principal cities in Europe using this system in 1868:

Glasgow, Scotland	population,	750,000
Perth "	"	36,000
Lyons, France	"	400,000
Toulouse "	"	150,000
Angers "	"	53,000
Genoa, Italy	"	165,000
		1,554,000

In all of these except Glasgow the system is a complete success. In Glasgow the supply was inadequate owing to the smallness and shallowness of the wells, which were only 10 feet in diameter and 6 feet deep.

The water works of Lyons are particularly noticeable and interesting to citizens of Cincinnati because the two cities have, in regard to this source of supply, so many features in common. They have about the same population; the large rivers on whose banks they stand both flow through populous alluvial basins; both are subject to excessive floods, and a large and deep gravel bar lies contiguous to both cities.

Inasmuch as, according to these accounts, the Lyons plant is a brilliant success, and under conditions so closely resembling our own, common prudence suggests a careful investigation to ascertain whether the same system is applicable here before committing ourselves to the expenditure of at least $6,000,000.00 to obtain impure muddy river water.

At this point in the discussion it may not be out of place to review briefly the surveys and examinations heretofore made for a new or enlarged water supply for Cincinnati. The data are obtained from the report of A. G. Moore, Superintendent of Water Works, for 1880.

VP 1622

HISTORY OF PLANS PROPOSED FOR NEW WATER SUPPLY.

"The first official record looking toward a new water supply is found in Minutes of Board, May 30, 1845, as follows:

"That a Committee be appointed to ascertain the practicability of bringing water into the city from either of the Miamis, and that said Committee be authorized to employ means to obtain the necessary information.

"Mr. Stephenson was appointed that Committee.

"The records show no action of Committee.

"In 1853, the Board ordered Prof. Locke to make analyses of the various waters in this vicinity, and his report shows that all the waters, except those from the Ohio river, are too highly impregnated with carbonate of lime for domestic use.

"In 1854 Superintendent Lewis Warden alludes to new supply, and, while commending the system for supplying New York and Boston, nevertheless is satisfied that no such consideration is here attainable from any contiguous stream within fifty miles. His opinion was based upon the surveys of the Miamis, Mad and White rivers.

"Mr. Irvin brings up the subject, in his Annual Report of 1857, of supplying the city by gravity in preference to the pumping system, on the point of economy, in which he states that this subject 'has been mooted at different times without giving much light in regards of real truth.' He obtained the levels of the feeders of the Miami canal at Middletown and Mad river, and, comparing these with the height of reservoir, finds the 'project not very plausible.'

"Mr. R. C. Phillips submitted, at this time, schemes for utilizing several water-sheds—one some miles above Brighton House, forty feet above Miami canal, with capacity of seventy millions daily supply, and another thirteen miles above the same place, and fifty-eight feet higher than the canal. His idea was to use the canal-bed as an equeduct to convey the waters to the city. The most important step toward securing a new water supply was made in 1865, when Council appointed a Special Commission to investigate and report on the project.

"They secured the services of Jas. P. Kirkwood, of New York, who made a thorough examination of all the available sources, and submitted an elaborate Report of his investigations, with the plans and recommendations for a pumping system, with subsiding and storage reservoirs, the site selected being this side of Crawfish creek, using Ohio river as a source. The estimated cost was $3,038,214.07."

"Markley Farm."

"On the 27th of April, 1871, the Trustees of the Water Works sent a communication to the Common Council recommending the purchase of the Markley Farm reservoir site.

"On June 9th a resolution was passed authorizing the Committee on Water Works to examine sites and employ a competent engineer to prepare plans, etc. In pursuance to this action, on July 22d, the Trustees of the Water Works employed Mr. T. R. Scowden as engineer to report on the subject. His report recommended the purchase of Markley Farm and his general plan embraced the construction of Pumping Works for two lifts, with a capacity of sixty million gallons daily. The total cost was estimated at $4,545,143.95.

"Superintendent Bell, in his report for 1878, has the following recommendations:

"I would recommend to your Honorable Board the project of setting aside a portion of the Water Works' revenue for the future extension of Pumping Works to Markley Farm. As the necessity for the removal of the present works to a more suitable location becomes more apparent each year, some action should be taken at an early date looking toward this change."

To which Superintendent A. G. Moore adds in his report of 1880:

"Responsive to these arguments, I regard the Markley Farm location as embracing all the advantages for an economical, copious, pure and intelligible water supply which may be realized."

There are 92 cities and towns in America using a natural system of filtration galleries or wells in bars or on river banks. The data are tabulated from Baker's Manual of American Water Works, 1890 and 1891. The classification adopted is only approximately correct. In many instances where the galleries are set back from the river bank, it is probable that more or less ground water is admitted, Kirkwood gives Lyons as an instance of such an admixture. The resulting injury to the water supply may be twofold. In calcareous formations the hardness is increased and, what is of graver importance, the water supply is liable, in some localities, to contamination by organic matter. Kirkwood however, suggests that an important advantage may sometimes result from removing the galleries some distance from the water line. He says, in his account of the Toulouse Water Works. "The body of sand and gravel referred to above, so much of it as lies below the level of the water in the river, it is superflous to say, is saturated with water, and this water, although evidently derived from the river and its affluents, has passed through such a width or depth of material at a very slow velocity on the wide plains above, as to have deprived it entirely of the matter which gives the muddy hue to the stream. In the filtering galleries, therefore, it is found colorless and limpid. *Immediately under the bed of the stream, or in too close proximity to it, this result would probably not have place."* Right here it should be emphasized that this opinion ought to have no controlling weight in any particular case, except to point out one important line of investigation. The sensible thing to do in all such examinations is to ascertain the facts by actual test. As will be shown further on, this can be easily and inexpensively done in our case.

In this connection another valuable suggestion by Mr. Kirkwood is important. Speaking of galleries of the Perth, Lyons, Toulouse, Genoa type, he says: *"These galleries are technically called filtering galleries, but in reality they are mere receptacles and conduits for gathering the water already filtered by a natural process. They serve nothing towards the filtration of the water, but only towards the collection of a portion of it, and its transmission to the pumping machines."*

It seems to the writer that this general statement should be taken with a reservation. With regard to any particular case its truth would depend on the following facts:

1st.—The ratio between the volume of the natural supply and that required for the city.

2d.—The size of the bar or natural reservoir.

3d.—The depth of the bar.

4th.—The rate of percolation or infiltration through the bar, depending upon the fineness or coarseness of the materials and of their mode of disposition or arrangement.

5th.—The "head" between the water surface in the river and the level at which the water enters the galleries, and, possibly?

6th.—The velocity of the river current.

It may be possible to make such a heavy draught on one of these underground reservoirs as to cause too rapid a percolation, thereby drawing sand and silt into the galleries; (as an instance, see Kirkwood's report on Angers); or even when this result is not produced, it may happen, especially in shallow submerged bars, that the water is drawn directly downwards through the gravel, thus converting the arrangement from an underground reservoir, as described by Kirkwood, into a natural filter But this would not necessarily forbid its use. The bar might have sufficient filtering capacity to deliver for all time the requisite volume of water, and of sufficient clearness and purity. That would be another point to be established by examination and experiment. Some bars are so situated that their top surfaces are scoured during floods, and a fresh covering is deposited during the subsidence of the water. Such filter would never become clogged, as the upper layer, which is the first to choke up,would be continually renewed by Nature. But in this downward filtration there would always be liability of some organic matter being carried into the galleries from the river above; so that even if the water so obtained were fully up to the standard of purity, it is highly probable that the supply obtained from the bottom current alone, i. e., the natural reservoir, would be still purer. The latter would therefore be always a preferable source.

ANALYSIS OF THE ABOVE DATA.

An examination of the records in the Manual leads to the probable conclusion that the majority of works in the list above referred to are, properly speaking, filters and not natural reservoirs—or are, as in the case of Lyons, a combination of the two.

Humber says, "The success of the system of filtration now generally adopted, like that of many other inventions and discoveries, has not been achieved without costly experience and failure of considerable magnitude."

Therefore it will be instructive to investigate and classify the causes of failure in the cases above cited.

1st. As to quantity. (a) The failure in quantity may be due to an inherent defect in the bar itself. It may be too small as to area or depth (more especially the latter); or the material may be so fine as to cause too slow a rate of percolation. All of these defects seem to have been combined at Glasgow. At Providence, R. I., the soil was not sufficiently porous. (b) The failures have been frequently due to improper construction of the galleries, especially in that they were not sufficient in bottom area and sometimes were too shallow. Kirkwood's records show that in every case described, except that of Genoa, the works as at first constructed were deficient in these respects, and had subsequently to be enlarged. At Angers the requisite extensions had not been made at the time of Kirkwood's report.

2d. Failure in quality. Our country furnishes several examples under this head. Two in our own State will be sufficient as illustrations, viz: Dayton and Columbus.

Dayton obtains Mad River water by 30 8-inch tube wells driven near both banks, connected by a 20-inch main passing under the river. The average depth of the wells is 40 feet. The supply is reported as sufficient, but owing to the calcareous nature of the gravel bar the water has a high degree of hardness. Owing to the open or porous texture of the bed it can have but a feeble filtering action. The Mad River is exceedingly foul and any ground water that might find its way into the tubes is liable to contaminating in the populous region above. In the case of the Columbus supply, (which is obtained from filtering galleries 10 feet below low water, extending across and under the bed of the Olentangy River), the water is too hard, and, as observed by the writer in 1881, it contained so much organic matter as to become very offensive after standing two or three days in the open air.

These and other similar examples show the importance of scrutinizing the character of the bar or gravel bed to be used as a filter or reservoir. Whereas in Dayton and Columbus the gravel is entirely of soft soluble limestone, and the texture of the bed coarse and open; permitting the water to flow freely through it; where the stream is foul, caused by its small volume and because it flows through a populous region; and where, morever, the bed itself is in an urban or suburban district necessarily involving surface contamination, all the conditions point to a hard, impure water supply. The only alternative is to look for another source of supply or to purify the one under consideration by an artificial process.

Two systems have been successfully and economically used on a large scale. One (mentioned in the recent report on the Public Water Supply of Cincinnati by a committee of the State Board of Health) is in use at Antwerp It consists essentially in passing the water through revolving cylinders containing bits of metallic iron. "By attrition fresh surfaces of the iron are constantly exposed to the water passing through the cylinders, the carbonic acid brought by the water dissolving a minute portion of the metal and forming a protosalt of iron. On issuing from the cylinders into the open air, the protosalt is converted, by the action of the atmospheric oxygen, into the insoluble ferric oxide, or iron rust. The action of the ferric oxide in its nascent state in impure water is to burn up, so to speak, the organic matter. In addition the ferric oxide, in its formation, encases in its flakes finely divided matters in suspension, forming a flocculent precipitate, which can readily be removed by rapid mechanical straining. For this purpose sand filters not more than 18 inches in depth are sufficient; and as the organic matter has been removed in large part before the water reaches the filter, only superficial cleaning is required." The following are the salient points of thls report of the Committee of the State Board of Health:

"Is it possible for Cincinnati to obtain a sufficiently pure water supply above local sources of pollution? This question should be fully answered before changing the present source of supply.

"Can Ohio River water, above the mouth of the Little Miami River, be so purified as to remove, or sufficiently minimize, the dangers attending the use of a sewage polluted stream, and justify Cincinnati in obtaining water from this source? This, it is believed, can be done."

"There are other processes of water purification that would very greatly improve the character of the Ohio River water, and it is earnestly recommended and urged that this be made a subject of careful inquiry by a competent commission before plans for obtaining a new water supply for Cincinnati are finally adopted.

"To sum up our conclusions:

"1st.—The present water supply of Cincinnati is dangerously polluted and should be abandoned as soon as possible.

"2d.—The Ohio River above all local sources of contamination offers the best available supply, and:

"3d.—This supply can not be safely used without purification.

The maximum amount of ammonia in the California water December 15, 1891 was .02 in 100,000, showing a bad water. The maximum amount of chlorine .83 in 1880, 1.70 in 1887 and 1.40 in 1891, an alarming excess of this most dangerous element above the safe limit and an increase in seven years of over 100 per cent.

The other process demanding notice is that of Dr. Clark, of Aberdeen, Scotland. This consists in precipitating the lime bi-carbonate by the addition of a solution of quick-lime. A proto-carbonate (whiting) is formed, which being insoluble, settles to the bottom in the form of a milky precipitate.

From an analysis by Mr. Dugald Campbell, of a sample of water from the new works at Canterbury, England, and submitted to Clark's process, it appears that the hardness before treatment was 14.9° and after treatment 3.8°. Of the latter, 2.34° was due to Sulphate of Lime, Nitrate of Lime and Silicate of Magnesia. Owing to the fact that these latter salts can not be removed from water by boiling nor by Clark's process, they are said to produce 'permanent' hardness in the water. It will thus be seen that the total reduction in temporary hardness of the Canterbury water was from 12.56° to 1.48°.

The analysis also shows 'that the softening process has practically no effect upon the aeration of the water, there being a loss of only 0 12 out of a total of 8.11 cubic inches.'

"Prof. Tyndall has recently applied the electric light to the comparison of different waters supplied to various towns; and the result is, that such apparently clear waters as those of Loch Katrine, seem, under this searching test, to be water of a muddy pool compared with the unyielding transparency of the Canterbury water, which is brought about mainly by the effective precipitation of foreign matters with the carbonate of lime in the softening process."

Both these artificial methods of purifying water are, as instanced at Antwerp and Canterbury, successfully and economically employed. In purity and clearness of the water, Clark's is unquestionably the most perfect yet devised for use on a large scale. The system used at Antwerp seems to be less costly and is susceptible of enlargement at less cost. But undoubtedly the plan of tapping a large supply already clarified by Nature is the best of all where it can be secured. Its advantages are the following:

1st —Its first cost is usually much less than that of a system of storage and service reservoirs.

2d —Where the natural supply is sufficient little or no reservoir is required.

3d.—The water is clear at all stages of the river.

4th.—Where a wide, long and deep bar exists, so that the galleries or driven wells may be in the stream some distance from the bank, the supply will usually be protected from contamination by mixture with ground or soil water.

5th.—The system can be readily enlarged from time to time to meet the increasing demands of the town.

6th.—Where the galleries or mains are ample, so as to maintain a low velocity of infiltration, the cost of maintenance of the system is small, and it is practically perpetual.

7th.—By having a proper number of mains connecting the galleries or banks with the pumping works the danger of a failure of the supply is reduced to a minimum.

Past experience shows that the following points should be kept in view in the selection of a source of river bar supply, and in the construction and operation of the works.

The source should be examined:

1st.—As to the topography of the river bottom and the relation of the site; as to its distance, elevation, difference between high and low water, etc.

2d.—The width and depth of the bar, and its texture, involving the rate of infiltration and the amount of silt resulting from different rates, so as to determine whether we are merely tapping a natural basin of clear water or whether a filtering action is set up.

3d.—The volume of the underground supply as compared to that required for the city.

4th.—Is the water hard or soft? If hard is the hardness permanent or temporary?

5th.—Is it clear at all stages of the river?

6th.—As to the organic amount of impurity in the water, especially immediately on the bed rock or very deep in the bar.

7th.—In this connection, if we are compelled to set up a partial filtering action in the bar, is the latter so open as to endanger the contamination of the underground water by drawing down that of the river immediately above, or the soil water from the banks?

8th.—If the bar acts in whole or in part as a filter, is there any danger of its becoming clogged in course of time?

The depth of the bar and its composition can readily be determined by borings. The rate of coefficient of infiltration is best found by sinking driven test wells in the bar.

The water so obtained can then be subjected to chemical and microscopical examinations.

The volume of the supply can be calculated from the dimension of the bar and the coefficient of infiltration.

If the test shows the water to be of standard quality we will then have data for determining the character, dimensions and details of the works and the approximate cost of the system.

Deductions from the surveys and examinations heretofore made for the Water Works.

The biological examination made recently by a committee of the State Board of Health proves that the water of the Ohio above the Little Miami is far too impure for use.

Test wells sunk by the recent Board of Experts, and at various other times in the valleys of Millcreek, the two Miamis, Sedamsville, etc , including deep wells, invariably yield too hard a water.

The well on the Dayton Sand Beach, although on the bank some distance from the water line gave a much softer water.

Some of the deepest wells, notably that at Sedamsville, contained an alarming amount of suspicious chemicals, especially of Chlorine, an unusual and surprising result in such deep wells.

The slight degree of hardness of the water from the Dayton Sand Beach would indicate that the bar was composed of rocks and sand from the silicious formations above, and not from the outpour of the local streams flowing through and surrounding calcareous beds

A high English authority, Dr. Letheby, recommended on the score of health that water of not less than 10 degrees of hardness be used; nevertheless this is so objectionable commercially, on account of its injury to boilers and to many manufacturing processes, that a much softer water is usually demanded, and 5 or 6 degrees would seem to be a fair compromise.

In designing the works, the collecting appliances should be of ample capacity, so that a very low speed of infiltration may result, thereby preventing the entrance of silt and the filtering action of the bar, or reducing that action to a minimum Several intake mains should be laid and so arranged that any engine may draw from any one of the mains

Where the mains leave the river, they should enter a tunnel through a water-tight bulkhead so strong as to resist the highest floods. All the steam connections should be above the high water line.

All parts of the pumps should be accessible for observation and repairs at all stages of water.

Comparing our surroundings with those of other cities using naturally filtered water, we find, that while but little systematic examinations in this direction have been made, the indications here are of the most encouraging character. With the exception possibly of Genoa, none of the cities enumerated in the above lists have as long and as wide a bar as ours, and judging from Yngling's well, our bar is deeper than any used in Europe.

The analysis shows that in regard to hardness and freedom from organic impurities the water from the Dayton Sand Beach is of high grade, as a whole far better than any other found in the neighborhood ; so much so that the Health Officer, in his report for 1880, recommended this as the best source of water supply.

The top of the bar has large areas two or three feet above low water; so that the galleries or intake mains could be laid during the summer in open cuts at small expense, and they would always be accessible for repairs at low water.

From appearances the bar has sufficient width for this purpose at a point not over half a mile from the pumping station. This point could, of course, only be determined by a careful examination. It would seem then that the environment offers us every inducement to give this system of water supply a thorough examination. especially as the works could probably be constructed at less cost than on any other system. There being no surveys or examinations on which estimates for such a plan could be based, it is of course impossible to approximate the cost of such works.

But in the way of suggestion only, and as a basis for the discuscusion of such a system, the writer ventures the following outline of plan;

An examination of the lines indicated above would show the extent and character of the bar, and the quality of its water.

The lowest point at which the bar could be tapped would also be ascertained.

A new site for a pumping station should then be acquired on the north side of Eastern avenue, above flood line, as far down stream as practicable from the lower end of the intake on the bar.

A tunnel at proper depth should then be driven under the avenue to the river bank, where its end should be closed by a water tight bulkhead wall. An ample number of intake pipes should pass from the pumping station, through the tunnel and bulkhead, to the collecting appliances in the bar. If the distance from the latter should not prove too great, the park below the Third street reservoir could be used as a site.

Duplicate lines of force mains should be laid to the Eden Park reservoir, remote from each other, so that if one were to break, it would not endanger the other.

Some new engines of the most approved design would undoubtedly be required. They could be erected and connected with the new force main without interfering with the present works. Such of the present engines as should be deemed worth retaining could be transferred one at a time to the new station, and set to work as soon as the connections were complete. When a sufficient number of the new engines were ready for work, one basin of the reservoir should be emptied, and the bottom washed clean with nozzle streams. The basin could then be filled with filtered water through this new force main. When the new station is complete the present force main would be connected with it, and the remaining basin emptied, cleaned and filled with crystal clear water. Then muddy water for Cincinnati would be a thing of the past.

It should be noted that in estimating the contamination of water by the number of pounds of sewage, so called, to 1,000,000 gallons, it is stated that when pure water is exposed to the atmosphere, especially in or near large cities, it receives contamination equivalent to from 1 to 1½ pounds of sewage to 1,000,000 gallons. Therefore, the larger the storage reservoir, the longer it would remain exposed to the air before use, and the greater would be its contamination from this source. Hence, when a city has its reservoir of filtered water under the bottom of the river bar, the smaller its service reservoir is the better. Whatever its size, the system would not be perfect, especially under the smoky skies of Cincinnati and in leafy Eden Park, unless the reservoir where arched over, like those of Paris and Marseilles, the arches being covered with earth to keep the water cool.

The collection appliances might be either galleries of masonry, or preferably lines of collecting mains somewhat similar to those proposed by Yngling. In any event the water should be taken from as great a depth as possible in the bar. Therefore, if galleries are used, they should be water tight and the water collected by wells permeable only near the bottom and sunk at intervals along the bottom of the galleries—as in the Angers water works.

The situation may be summed up in a few words:

1st.—All experts who have examined the subject concur in recommending the Ohio river as the best source of water supply for Cincinnati.

2d.—All are equally agreed that the present supply below the mouth of the Little Miami is dangerously unfit for use.

3d.—While the water above the Little Miami is less foul than that below, the recent examination by the Committee of the State Board of Health proves the former to be unfit in its present state for the use of human beings.

4th.—The Committee therefore recommended that it be filtered and purified, and adds: "It is earnestly recommended and urged that this be made a subject of careful inquiry by a competent commission before plans for obtaining a new water supply for Cincinnati are finally adopted."

5th.—More than 1,000,000 people in Europe and 1,250,000 in America successfully use naturally filtered water from the banks or bars of rivers—not counting inland towns using driven wells.

6th.—Appearances strongly indicate that Cincinnati is more favorably situated for the use of this system than any other city in the above lists.

If the above premises be correct, a failure to make a thorough examination with reference to this system would be reprehensible negligence on our part.

REMARKS ON A NEW WATER SUPPLY FOR CINCINNATI.

By G. Bouscaren.

The principal factors to be considered in designing water works for a city are the QUALITY, the QUANTITY and the PRESSURE of the water to be furnished.

QUALITY.

The objectionable features in water are, by order of importance—POLLUTION, HARDNESS and TURBIDITY.

Water is said to be polluted when it contains elements injurious to health. The most dangerous of these elements are germs of diseases and organic matter in dissolution, which may not be visible to the naked eye. Perfectly clear water may be badly polluted and extremely unwholesome.

Hard water contains mineral salts, principally carbonates, sulphates and chlorides, in such proportion as to render the water unfit for washing and cooking, for the production of steam and for many industrial purposes.

Turbidity is due to solid bodies, generally clay and fine sand, held in suspension in the water. Turbid water is not necessarily unwholesome, unless it contains organic matter or is otherwise polluted, but it can not be used without clarification for a great number of manufacturing processes. It causes a deposit of sediment in the distributing pipes which is always a source of annoyance and expense, and its usage for domestic purposes is, to say the least, very unpleasant.

Cincinnati is limited, in its choice for a water supply, between the Ohio River and the underground water found in the gravel and sand formations of the valleys tributary to the Ohio.

The eminent engineers employed three years ago by the Board of Public Works to give advice on the best source of supply, recommended the Ohio River. The other alternative was rejected for the very good reasons that the underground water referred to is ***hard,*** and that the possibility of procuring it in sufficient quantity to supply the city permanently, must be, to a certain extent, a matter of experiment.

On the other hand, the river can always furnish an abundant supply Its water is soft, about one-tenth only of the drainage area of the Ohio above Cincinnati being of a limestone formation. The water, if taken above the local sources of contamination, as recommended by the board of experts, is wholesome; by reason of the great distance of other large cities above Cincinnati and of the great volume of discharge of the river.

The greatest fault that can be found with the river water is its turbidity.

The methods in vogue for clarifying turbid water are:

1st.—By drawing it out of the river through the medium of filtering galleries or wells, whereby the water is made to percolate through sand or gravel on its way to the pumps and arrives there clear.

2d.—By storing it in reservoirs a sufficient length of time to allow clarification to take place by sedimentation.

3d.—By filtration between the pumps and the distributing pipes, which can be accomplished either by filter beds or machine filters.

Filtering galleries are expensive: they are "per se" experimental works; they very often become inoperative after a time by the puddling of the gravel or sand bed in which they are built; they are at all times of difficult access for repairs and for long periods of time entirely inaccessible.

They are opened further to the grave objection of supplying sometimes hard underground water instead of river water.

Such was the case with the well originally sunk at the old Covington Water Works to feed the pumping engines. It was finally abandoned and a direct intake pipe was laid from the pumps into the river

The second mode of clarification, by subsidence in reservoir, is especially adapted to the Ohio River water, on account of the large proportion of clay in the water. It is now a well established fact that the clay acts, in a measure, as a coagulent and carries with it to the bottom the greater part of the organic matter and of the Bacteria that may exist in the water, which is thus *purified* as well as *clarified.*

A settling reservoir, having a capacity of ten days supply and provided with the necessary facilities for cleaning periodically by flushing, would therefore be a very desirable feature in a new plant for the city, especially if the water is not to be filtered.

It is not to be expected however, that such reservoir would furnish *sparkling* water. The great bulk of the sand and clay would indeed be eliminated, but the water will always retain a milky appearance due to the finer particles of clay which filtration alone can remove.

Filter beds are extensively used in Europe. They are expensive to construct as well as to maintain properly, which requires cleaning at regular intervals of time. For this reason they are a feature of rare occurance in American water works, and their adoption for Cincinnati would hardly meet with much favor, considering the necessity which exists of accomplishing as much as possible with a moderate outlay.

Mechanical filtration is less expensive in cost of first establishment and has been successfully applied in a number of cases, although never on such a large scale as would be required for the treatment of the entire supply for Cincinnati.

There are a variety of machine filters in operation, the most successful ones being those where a coagulent is used to assist in separating the finer impurities.

A considerable amount of mechanical power is required to force the water through the filters and a certain amount of water must be used daily for the frequent flushings required to maintain the filters in good working order. This, with the expenditures for repairs and for the wages of the men employed to operate the filters, constitute the cost of operation.

The percentage of this item to the total rate of cost of the water furnished, will vary largely with circumstances, but it will always be sufficiently great to be taken into consideration in determining to what extent filtration shall be applied.

It seems a useless expenditure of money to filter the water used for street sprinkling and sewer flushing, for elevators, for fire service and for many other purposes where the partly clarified water from the settling reservoir

would answer quite as well. The problem of separate delivery of both kinds of water can be solved either by two distinct systems of distributing pipes, or by confining the delivery of the filtered water to certain parts of the city where the demand for it is greatest. This latter alternative is the less expensive of the two and could readily be applied in the case of Cincinnati, by connecting the filtering plant to one or two only of the three divisions of the service, viz: the HIGH, MIDDLE and LOW service.

QUANTITY.

It has been recognized from time immemorial that the good health and comfort of a population call for an abundant supply of water. The grand old aqueduct of Rome, under the Caesars, carried over 800 gallons per day to every inhabitant of the Eternal City. We manage to get along with a great deal less now. The daily consumption per capita in the large cities of Europe seldom exceeds 50 gallons. In the United States the corresponding figures are about twice as large. The following are taken from the Manual of American Water Works for 1889-1890:

New York, before the last extension of the Croton Works	66 gallons.
Philadelphia	102 "
Boston	88 "
Baltimore	92 "
Pittsburgh	158 "
Buffalo	170 "
Cleveland	100 "
Chicago	114 "
St. Louis	80 "
Louisville	70 "
Kansas City	90 "

As the pumpage is not generally measured, but is computed from the number of revolutions of the pumping engines, the above figures are probably in excess of the actual consumption. These figures necessarily include the waste, which is a very important item where meters are not in general use.

From Mr. Arthur Moore's last report the rate of consumption in Cincinnati seems to have been about 120 gallons. Considering the bad condition of the pumps which served to gauge the delivery, it is likely that the correct figures would hardly exceed 100 gallons.

Making allowance for the probable increase of population in the next decade, and for the higher rate of consumption during the summer months, it would not be prudent to provide machinery for a daily pumpage of less than fifty million gallons. This would require a pumping plant of seventy-five million gallons total capacity, divided in three tiers, two of which being in service, with the third one in reserve by rotation. The Conduits, Engine House and Intake should be proportioned for a demand of not less than seventy-five million gallons daily.

PRESSURE.

Sufficient pressure in the mains to insure good and regular service in all the ramifications of the pipe system, is an essential feature in a well de-

signed system of water works. The pressure required will necessarily vary with the elevation of the locality above the base of supply and the frictional resistance to be overcome by the water in reaching it.

Pressure in the mains, representing stored energy, equivalent to money spent in coal burnt under the boilers, becomes an expensive luxury when used beyond the amount necessary for a good service. For this reason the division of the distribution system in Cincinnati into a high, middle and low service, according to the elevation of the districts served, is eminently proper and should be preserved. The new machinery and reservoirs should be designed with this object in view.

GENERAL.

In their report to the Board of Public Works, in 1889, the commission of experts have defined clearly what the main features of a new plant for Cincinnati should be.

They were all men of experience and ability. They gave the subject a careful consideration and were very guarded in giving their opinion, not to commit themselves on doubtful points. In my judgment, no important departure should be made from their recommendation without very potent reasons, and experimental ventures should specially be avoided. If it is true that experiments are the foundation of engineering, it is also fundamental of good engineering that experiments should first be tried on a small scale as an intitial step to larger ones, and that no unnecessary chances be taken on the final success of great undertakings.

A discussion of the details of the work would be premature and out of place here, but the thought that a good plan may easily be spoiled in the execution suggests itself in connection with the proposed plant on account of the mistakes which are being frequently made in buying cheap machiney to do expensive work.

The increased cost of operation in such cases generally exceeds the interest on the additional sum which would have been required to have made the machinery adequate to its work in all respects, without speaking of the great annoyance, inconvenience and expense arising from frequent breakdowns.

It is to be hoped that the mistake will not be made in this case, but that the BEST and not the CHEAPEST machinery will be adopted for our new water works.

May 26, 1892.

CINCINNATI'S WATER SUPPLY.

BY EDWARD FLAD.

The City of Cincinnati has for many years been in need of a new system of Water Works, and numerous efforts have been made towards the establishment of a system of works commensurate with the present and future needs of the city.

Expert opinions and reports have been obtained in great profusion, some of them gratis, and others for value received; and though the former class have indicated considerable difference of opinion, it is encouraging to note that, in the main, there is a sufficient agreement between the opinions of the leading engineers of the country who have devoted their attention to the subject, to leave no doubt, at least in the minds of such who are willing to abide by the decision of professional men rather than laymen, as to the general plan upon which new water works should be constructed.

So much has been written upon the subject, that it is scarcely possible to offer an opinion or argument that has not already been advanced. The report, which bears perhaps the greatest weight of professional reputation, is the one made by a committee of experts to the Board of Water Supply Commissioners of Cincinnati, in February, 1889, and as the writer is, in the main, in thorough accord with the opinions and recommendations advanced therein, having had an opportunity, during some six months of official connection with the above Board, to study the various phases of the subject, it may be as well to state, at the beginning, that the general plan outlined below is identical with the recommendations in the report above referred to.

SOURCE OF SUPPLY.

Of the various sources of water supply which have been suggested for Cincinnati, the only one which is available within reasonable limits of expenditure, and without any risk as to quality and quantity of water obtained, is the Ohio river.

It has often been urged that a system of tube or driven wells, located on the "Dayton Sand Bar," or in "Turkey Bottom," would afford an amply and wholesome supply, and the prospect of clear water to be obtained in this manner has lent an attractiveness, especiaally in the eyes of laymen, to this proposition. Numerous analyses of the water furnished by such wells, except where they are located so as to furnish only river water, indicate a degree of hardness far beyond what is allowable, varying from 20 to 60 degrees, and even if wells or galleries could be so located as to furnish river water filtered throngh sand, with practically no admixture of upland water,

the reliability of a continued abundant supply is not indicated, either by the experience of other localities or by sound reasoning. Works built upon such a plan would be but a costly and uncalled for experiment not warranted by existing conditions.

The recent experience of the city of Nashville, Tennessee, in the matter of a filter gallery, located in a gravel bar, is instructive in this connection. Suffice it to say that the experiment was tried there, and though at first the results were satisfactory, after a few years of service a direct inlet connection to the Cumberland river was found necessary, the filter gallery being abandoned.

LOCATION OF INTAKE.

The location of the Intake should be above any present or probable future source of pollution, and consequently at some point above the mouth of the Little Miami River. The conditions required for a suitable location of the intake, viz: permanent channel, and possibility of erecting an inlet tower without interfering with navigation, are found on the Ohio shore at Markley Farm, at a distance of about 10⅓ miles from Eden Park Reservoir; and on the Kentucky shore, just above the mouth of the Little Miami a distance of about 7 2 10 miles. The Markley Farm location offers a site for a storage reservoir of a capacity which has been estimated at 300,000,000 gallons, with a high water line at an elevation of 75 feet above the high water line of Eden Park reservoir, but with the improved pumping machinery of the present day, the additional expense involved in constructing this storage reservoir and laying the increased length and size of water mains, cannot be justified in view of the favorable location for settling reservoirs and pumping station existing on the Ohio shore between the Miami river and the town of California.

OUTLINE OF PROPOSED WORKS.

It is therefore proposed to locate the pumping station and settling reservoirs on the Ohio river between the Little Miami river and the town of California; with an inlet tower on the Kentucky shore, opposite the pumping station; a tunnel under the river connecting the two, to lead the water to the pumping station; and a series of force mains leading from the pumping station to Eden Park reservoir.

CLARIFICATION OF WATER.

Experiments made by the writer in January and February, 1889, indicate that a large portion of the suspended matter can be removed from the water by subsidence An average of eight experiments, when the river water was very turbid, containing from 0.26 to 0.59 parts, by weight per thousand, of silts in suspension, show that 76.8 per cent. of the silt was removed by an average settling of 37.6 hours. As much as 85 per cent. of the suspended matter was removed by 40 hours settling.

While it is considered desirable to construct settling reservors in order to remove the greater part of the suspended matter, it would not be practicable to attempt to clarify the water entirely by simple subsidence Some form of filtration or settling, with the aid of coagulents, must be resorted to. Experiments on filtration of the Ohio water were commenced with the view to obtaining full information as to the methods best adapted to the conditions existing in Cincinnati, but were not carried to a conclusion. Further exhaustive experiments will be required before any definate plan could properly be recommended for so large a system under conditions not analogous to those existing in Europe, where alone we are able to obtain data upon filtration upon so large a scale. Moreover it is probable that the public mind is not yet educated to the desirability or necessity of supplying clear water, so that the additional expense of so doing would not be justifiable at present, although undoubtedly the works should be planned with the intention of ultimately furnishing perfectly clear water.

Sufficient property should be acquired for filter beds, and the design of the settling basins, location of pumps, etc., should be such that filter beds may readily be added at any future time with the least possible expense.

COST OF WORKS.

The cost of works as outlined above, even if built on the most liberal plan, with provisions for future economical extensions to a capacity of 100 million gallons per 24 hours, need not exceed 4¼ million dollars for a supply of 50 million gallons per 24 hours, with an addition of 1½ million dollars when the supply is increased to 75 million gallons. The works could be completed within from 4 to 6 years.

According to the requirements of the new water works bill, passed by the General Assembly of Ohio, the works must be built within the State of Ohio. It is assumed that this requirement would not prevent the location of the inlet tower on the Kentucky shore, otherwise it would become necessary to locate the inlet at Markley Farm, with an additional length of pipe line of about three miles, but even in this event the construction of the Markley Farm reservoir would not be necessary or advisable.

The requirements of Cincinnati in the matter of an improved water supply are well acknowledged on all sides. In a work of this magnitude it is, of course, of the utmost importance that politics should not be made the basis of appointments.

In voting upon this question, however, it should be remembered that the fear of corruption, often entirely unfounded, has caused the abandonment or injurious delay of many public improvements well and skillfully planned, in the interest of those who rejected them.

St. Louis, Mo.. Feb. 26, 1892.

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